International Journal of Scientific Engineering and Technology
Volume No.5 Issue No.6, pp: 507-511

ISSN:2277-1581
01 Nov. 2016

Novel Image Enhancement Technique using CLAHE and Wavelet Transforms

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Abstract*—This paper presents a new method for image enhancement which includes both resolution enhancement and contrast enhancement. The proposed method merges SWT-DWT which is for resolution enhancement and CLAHE-SWT which is for Contrast enhancement. SWT is used in combination with DWT for enhancing the resolution of an image. (CLAHE) is a powerful method for contrast enhancement.SWT is used in combination with CLAHE to mitigate noise effects. The proposed method gives better results than existing techniques and it is proved with PSNR, Standard Deviation and RMSE and visual results.

Keywords—***Contrast limited adaptive histogram equalization(CLAHE),Discrete wavelet transform(DWT), Stationary wavelet transform,(SWT), Bi-cubic interpolation, Peak signal to noise ratio(PSNR)***

I. Introduction

Image enhancement means to polish up the image so that enhanced image looks better than original. Resolution enhancement and contrast enhancement both are important features in image processing field. Wavelet transform has become most salient tool for image enhancement applications.

Resolution is the ability of image to show its details. Hassan Demirel and Gholamreza Anbarjafari proposed the method[1] of image resolution enhancement using DWT . This method decomposes the image using DWT, and high frequency components are bi-cubic interpolated. However in this method noise has its significant effect. To mitigate noise increment they introduce SWT as an intermediate stage and proposed the method [2] of image resolution enhancement using DWT and SWT.

Contrast enhancement is an improvement of image quality to better and more understandable level for feature extraction or image interpretation. Contrast enhancement techniques have been classified into two principle groups-spatial-domain, transform-domain based methods. Spatial domain techniques like logarithmic transforms, power law transform, histogram equalization methods are based on direct manipulation of pixels in the image plane, while transform domain techniques are based on the manipulation of the transform of the image rather than the image itself. Histogram equalization is a method of contrast adjustment [3] using the image histogram in image processing. This method increases the global contrast of images by applying a gray level transform which tries to flatten the resulting histogram. Histogram equalization works best on over or under exposed image, which has narrow contrast range. Since the HE is applied on the whole image, the local details are not enhanced effectively. To overcome these drawbacks, local histogram equalization (LHE) based methods are proposed.

Pizer[4] proposed the contrast adaptive histogram equalization (CLAHE) which is an LHE-based image enhancement method. Histograms that are above the clip limit are clipped and distribute to the other histograms of different regions which have histogram height below the clip limit. In transform-domain based methods decomposition is applied i.e. transformed into frequency domain before image enhancement, which prevents image artifacts and improves image quality. Huang lidong proposed [5] CLAHE-DWT method which is one of the contrast enhancement method and uses the combination of both DWT and CLAHE. Drawbacks of CLAHE are overcome by this CLAHE-DWT method.

In this paper, we introduce a new contrast and resolution enhancement technique which can improve resolution, contrast of image and avoid over enhancement, reduce the noise effects. This new method combines CLAHE with SWT for Contrast enhancement and DWT with SWT for resolution enhancement. In this proposed method input image is given to both DWT and SWT for resolution increment. Bi-cubic interpolation is used for sharper details. Resolution enhanced image is given to SWT for different frequency sub-bands. SWT minimize the loss in terms of down sampling which occur in DWT because of down sampling. CLAHE is applied to low frequency components only. This mitigates the effect of noise during process of contrast enhancement. Finally inverse DWT gives contrast enhanced image. Noise effect can be further decreased by taking the average of original image and output of inverse wavelet transform.

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II . Related work

In this section we provide the work which is related to proposed method that is about CLAHE and CLAHE-DWT.

CLAHE:. The main steps of CLAHE are given as follows

1. Divide the input image into tiles.

2. Set the clip limit, clip the histograms above clip limit and redistribute to other sub-blocks.

3. Apply histogram equalization to the each tile.

4. Interpolate the neighboring tiles.

Selection of tile size and clip limit is crucial for CLAHE because these parameters mainly control image quality. These parameters of CLAHE are determined based on image entropy . Image entropy is proportional to the distribution of histogram. Selection of tile size and clip limit follows [7] the below steps. 1. Set tile size as [8 8], vary the clip limit and apply CLAHE to input image.
2. Find entropy of CLAHE output, maximum entropy gives the best clip limit.
3. Update the above obtained clip limit, now vary the tile size from [2 2] to [32 32].
4. Repeat the step 2, maximum entropy gives the best tile size.
5. Update the tile size with value obtained above and performs the CLAHE with these parameters.
Discrete entropy is defined as [6] follows
$H(x) = -\sum_{i=1}^{N} P(x_i) log_2 p(x_i)$---------(1)
CLAHE-DWT: This method uses the combination of CLAHE and DWT to eliminate the drawbacks of CLAHE. Applying CLAHE to low-frequency components only reduces the noise. The Weighted average of the original image and reconstructed image alleviates the contrast overstretching. Pixels with higher intensities are enhanced less because of proportionality of weighting factor with pixel intensities. Choosing of weighting factor has significance and it is selected based on local entropy increment (LEI).

III.PROPOSED METHOD:

DWT-SWT&CLAHE-SWT: This proposed method uses the combination of DWT-SWT for resolution enhancement and CLAHE-SWT for contrast enhancement. First, input image of size [256×256] is decomposed using both DWT and SWT using Haar mother wavelet to get the low-frequency components and high-frequency components individually. The Haar wavelet is the simplest wavelet of all other wavelet families in terms of computation of wavelet coefficients. Fig. 1 shows the flow chart of proposed method. LL, LH, HL and HH are sub-band images obtained by applying DWT.

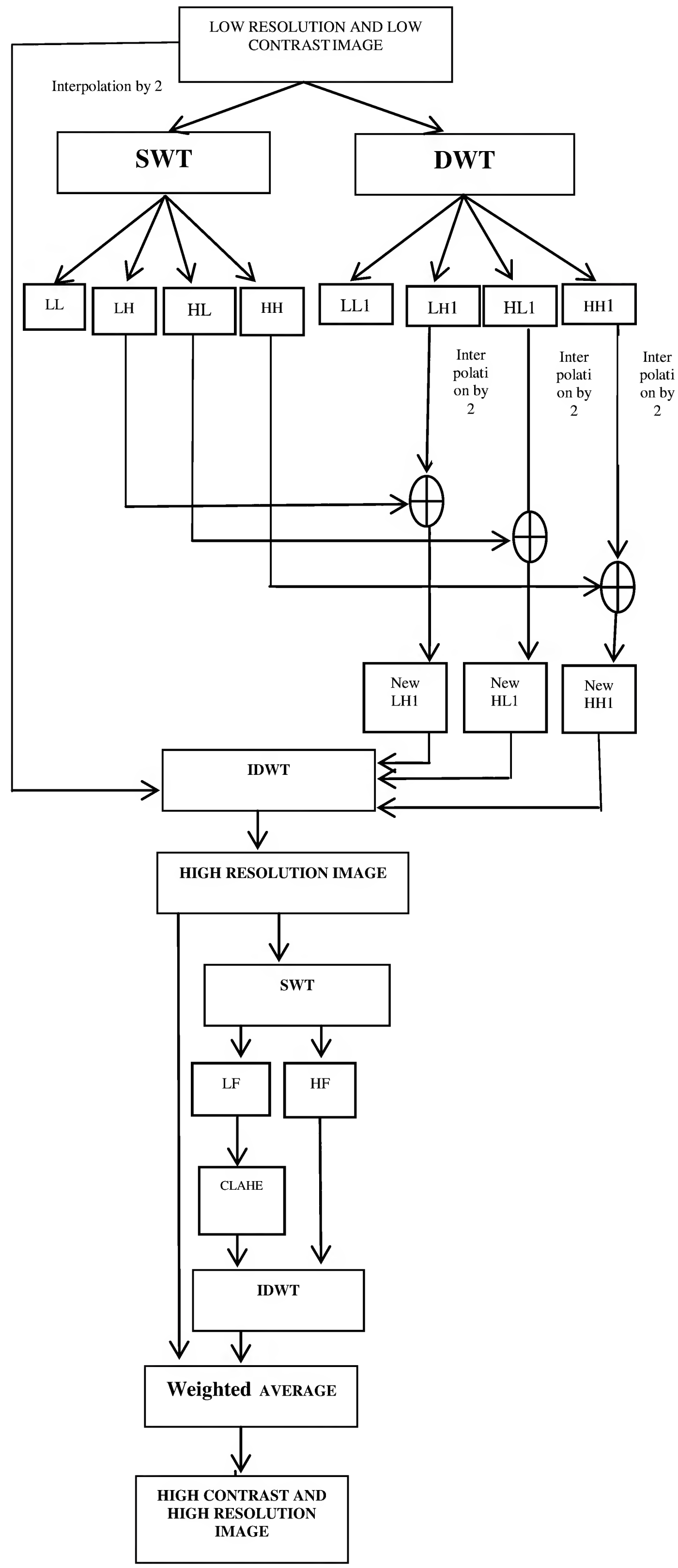

FIG.1 Flow chart of DWT-SWT&CLAHE-SWT (PROPOSED METHOD)

LL is the low-frequency information obtained by applying low pass filters and it is the approximation of original image with half size of the original image. LH, HL and HH are the vertical ,horizontal and diagonal information respectively. LL1, LH1, HL1 and HH1 are the sub-band images obtained after applying stationary wavelet transform(SWT).The stationary wavelet transform (SWT) is used to reduce the pixel loss which occurs in discrete wavelet transform(DWT) because of down-sampling. High frequency sub-bands of DWT are interpolated with factor 2 with the help of bi-cubic interpolation. Bi-cubic interpolation method uses the weighted average of neighboring sixteen pixels to estimate the intensity value of the middle pixel. This method gives excellent results both in calculation speed and quality of transformed image. Interpolation increases the number of pixels in a given image. High frequency sub-bands of SWT and interpolated sub-bands of DWT are combined. By taking the Inverse DWT of low frequency sub-band and new sub-bands we get the high resolution image with size [512×512].

Now the image is resolution enhanced but contrast of image is still poor .To improve the contrast of image we are using the CLAHE. First Resolution enhanced image is given to SWT.SWT is preferred over DWT because of its self-property of no down sampling. This is the main advantage of SWT over DWT in terms of pixel loss. Now, CLAHE is applied to low frequency sub-band. This is because high frequency sub-bands contains most of noise and by applying CLAHE to these sub-bands also causes noise increment. Because of this CLAHE is applied to low frequency sub-bands only. By taking the Inverse transform of CLAHE applied sub-band and high frequency bands we get high contrast image with size [512×512].On taking the average of low contrast image and resultant of Inverse transform noise can be further be reduced. Finally resultant image is both resolution enhanced and contrast enhanced.

IV. RESULTS & ANALYSIS:

In this experiment, proposed algorithm has been used for analysis of grey and color images. . The performance of proposed method for gray and color images is compared with both contrast enhancement (HE, CLAHE and CLAHE-DWT) and resolution enhancement (DWT and DWT &SWT) methods with different parameters (peak signal to noise ratio (PSNR), noise estimation (NE) and root mean square error (RMSE)). Both visual results and quantitative results are confirming the superiority of the proposed method. **Figs**.2,3&4 show the effectiveness of the proposed method over the standard image contrast enhancement and resolution enhancement techniques. Different images with different features are used for comparison. From Fig.2 we see that input image is grey scale image with size [256×256] and the resultant image of size [512×512] with sharp details and with high contrast image.Fig.3 represents the proposed method for color image. Fig .3(d) shows the output of CLAHE method. However in image details are over enhanced. Fig .3(e) shows the resultant of proposed method. On comparing with 3(d) proposed method resultant mitigate the contrast over stretching.

Peak signal to noise ratio (PSNR): It is the ratio between the maximum possible signal powers to the noise power. Here noise means mean of square of error between input image and enhanced image and it is called as mean square error (MSE), it is defined as follows

$$MSE = \frac{1}{MN}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad \text{------(2)}$$

Where M, N are the height and weight of the input image .K is the output enhanced image. The peak signal to noise ratio for gray scale image is given

$$PSNR = 10\ log_{10}(\frac{255^2}{MSE}) \quad \text{-------(3)}$$

Since color images have three deferent channels for color representation, mean square error (MSE) for color images is given as follows[10]

$$MSE = \frac{1}{3MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[(R_{i,j} - R^*_{i,j})^2 + (G_{i,j} - G^*_{i,j})^2 + (B_{i,j} - B^*_{i,j})^2]$$

M, N are the dimensions of the image $R_{i,j}$ represents R channel color component of the input image at pixel location (i ,j) and $R^*_{i,j}$ represents R channel color component of the output image at pixel location (i ,j) .

NOISE ESTIMATION (NE): It is used to measure the noise amplification during the process of resolution enhancement and contrast enhancement. For the estimation of noise ,noise is added to input image with mean zero and with a variance of **2.56**. Table 1 gives the psnr , rmse , standard deviation values of gray scale images and color images individually.

V . CONCLUSION

In this paper we present a novel image resolution enhancement and contrast enhancement methods, which combine the DWT-SWT with CLAHE-SWT. In this method the image is decomposed into sub-bands by both DWT and SWT. The high frequency sub-bands of DWT are interpolated and combined with high frequency sub-bands of SWT. This increases the resolution of image .CLAHE is applied to only low-frequency sub-bands of SWT. This reduces the effect of noise. Visual results and quantitative results (PSNR, NE, RMSE) show that proposed method performs better than other existing methods.

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GREY SCALE IMAGES:

(a)[256×256]

(b)[512×512]

(c)[256×256]

(d)[256×256]

(e)[256×256]

(f)[512×512]

Fig 2. **Gray Scale Image.** a) ORIGINAL IMAGE (b) DWT-SWT c) HISTOGRAM EQUALIZATION d) CLAHE e) CLAHE-DWT and f) PROPOSED METHOD

COLOUR IMAGES:

(a) [256×256]

(b) [512×512]

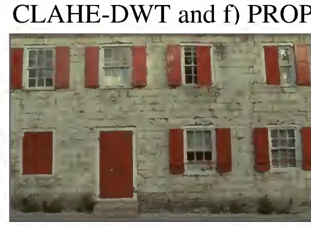
(c) [256×256]

(d) [256×256]

(e) [256×256]

(f) [512×512]

Fig 3. **CAPS Image.** a) ORIGINAL IMAGE (b) DWT-SWT c) HISTOGRAM EQUALIZATION d) CLAHE e) CLAHE-DWT and f) PROPOSED METHOD



(a) [256×256]

(b) [512×512]

(c) [256×256]

(d) [256×256]

(e) [256×256]

(f) [512×512]

Fig 4. **WALL Image.** a) ORIGINAL IMAGE (b) DWT-SWT c) HISTOGRAM EQUALIZATION d) CLAHE e) CLAHE-DWT and f) PROPOSED METHOD

Table 1. Comparison of Proposed method with other methods using Average values of all 3 image			
ON AVERAGE	**PSNR(db.)**	**NE(σ)**	**RMSE**
HE	53.75	12.73	17.79
CLAHE	52.45	16.00	17.24
CLAHE-DWT	55.59	10.43	11.77
DWT	36.2263	32.38	20.74
DWT&SWT	43.0733	19.55	14.33
PROPOSED METHOD	58.24	04.50	05.30

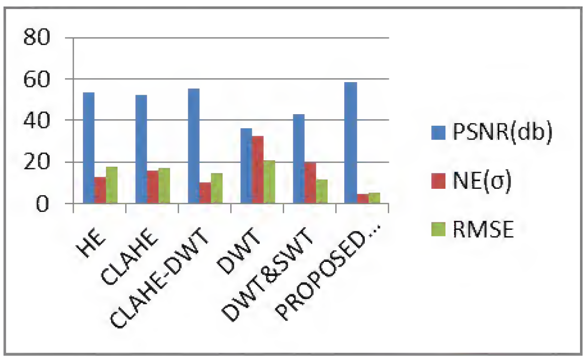


Fig. Comparison of PSNR, Noise Estimation, RMSE of existing methods vs. proposed method.

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